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HERBARIA ARE WORTH HAVING, BUT WHY?

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INTRODUCTION

At present there is great talk about the loss of biodiversity and how urgent steps must be taken to document, conserve and manage the dwindling plant and animal resources of the world. As a result, taxonomists are at the forefront of scientific endeavour for the first time for many years. Perversely, however, many taxonomic institutions, faced with financial difficulty or ruin, are having to ask fundamental questions about their activities and collections. In this context, I offer a short essay on herbaria, which I hope will in some small way contribute to an understanding of their value, even if only by providing further discussion. I must emphasize that the views expressed are mine, not those of my institute, though both coincide in one important essential : our desire to see herbaria (in particular, on the occasion of its bicentenary, the Central National Herbarium in Howrah) flourish.

Preliminaries : Are herbaria essential, in the sense that plant systematics would not have developed without them? The short answer is no. The study and documentation of plant diversity could have proceeded without the accumulation of millions of dried or pickled specimens in herbaria. The Central National Herbarium and the herbarium of my own institute, the Royal Botanic Garden, Edinburgh, have both played an extremely important part in supporting taxonomic research, but without them plant taxonomy would still have existed, though it would certainly have developed more slowly and along different lines. There are two easy ways to demonstrate this. Firstly, many of the smaller eukaryotes cannot be preserved effectively as herbarium specimens and yet they have been studied and classified: I admit that the classifications are often not very satisfactory, but that is more because of a lack of attention, technology and funding than because it is difficult to preserve them. Secondly, it is well known that human cultures that know nothing of modern science can still develop highly discriminatory classifications of the organisms around them (e.g. see Mayr 1969), especially those useful for food or medicines.

Thus, if fire, flood and pests were to destroy all the herbarium specimens in the world, taxonomy would survive, though it would take a long time to make good the damage. We might even cheer the loss of some inconvenient types, which undermine the traditional usage of long cherished names. In my own field, diatom systematics, the study of early nineteenth century types has not infrequently led to embarassing discoveries, requiring action to conserve or re-typify the names of large and widespread genera (e.g. Håkansson & Ross 1984). What time and effort could have been saved if the types had been lost! I have often wished too that diatom shells were less durable and made poorer herbarium specimens, since then diatom taxonomists would not have been able to act as though the shell is the whole organism, to the detriment of taxonomy and our knowledge of diatom cytology and life cycles.

Of course, even if all the existing types were destroyed, others could be designated, but then, do we actually need type specimens? Perhaps we don't. This is not such a heretical notion as it might appear. Stirton *et al.*(1990) claim that a system that "decides .... nomenclatural priority on published descriptions and not type specimens, is unworkable" but this simply isn't the case. After all, we have to do without type specimens altogether for most small algae, where published illustrations, interpreted by the figure legends and written descriptions, have perforce to serve as the types. Recent examples of taxonomic work on such organisms are the papers on *Pyramimonas*, by Moestrup & Hill (1991), and cryptomonads, by Hill (1991). What happens if a type illustration later proves inadequate and could refer to any one of several, clearly distinct taxa? Well, then the concept of the species has to be refined; the type itself is subject to interpretation and redefinition, and new images and descriptions must be given to clarify what each name refers to (e.g. see Hill 1991). It is not obvious to me that this system is inherently less satisfactory than the more rigid typifications of higher plants, which depend on a few specimens, located in one or a few herbaria. Since it is an image, the type of a perishable alga can be duplicated endlessly and distributed world-wide, which can rarely be done with type specimens.

Thus, although International Botanical Congresses have decided that the correct name for a preservable plant is to be determined by reference to a type specimen, we should remember that this is only a convention, which might be called into question if the financiers of science were to decide that this is too expensive and inefficient a way to provide stable nomenclature.

It might seem from this argument that I am saying that most herbarium specimens should be pulped, as was suggested by Clifford *et al.* (1990). Far from it. That would be pure vandalism. However, we must not seek to defend herbaria for the wrong reasons. Tradition alone is insufficient justification for herbaria and does not satisfy accountants.

Doubts : What, then, are the purposes of herbaria and do herbaria have a future? Forman & Bridson (1989) give four functions : ''a store or reference material ... a means of identification, by matching unnamed plants with named specimens in the collection ... an arbiter of correct names .... a comprehensive data-bank.''

In relation to the idea of a comprehensive data-bank, Forman & Bridson (1989) suggest that ''ideally the collection should fully represent the diversity and distribution of the region's vegetation'' Taken to extremes this would mean that every plant of every species would have to be represented within the herbarium, with full information about its (former!) location. This, of course, is not what Forman & Bridson intended and it is unfair to imply that they did, but then, how many plants should be collected? The same question can be asked about collections of live plants or seeds made for *ex situ* conservation. Only a complete collection will conserve all of the genetic diversity within a particular species, but this could be contemplated only *in extremis,* where a species is already extremely rare and will not survive in the wild. There is a ''fractal'' problem here, akin to the problem ''how long is the coastline of India?'' The length that will be measured depends on the scale of measurement; looked at in detail, tracing around every boulder, the coastline is much longer than it appears on the page of an atlas. Likewise, the size of collections necessary to represent the diversity and distribution of the flora in a given area will depend on how much detail is required. In the early phases of a taxonomic investigation I may be satisfied with knowing merely that a particular species exists; a few specimens, with some duplicates, will suffice. Later I may want to know whether the species is a narrow endemic or found on every continent; later still, my attention may shift to detailed mapping, to provide a basis for conservation. Should I collect more and more herbarium specimens of the species as I probe further into the minutiae of its distribution? There must come a point where further expenditure on mounting, cataloguing and storing specimens cannot be justified. On the other hand, if I don't collect sufficient voucher material, you will not be able to check that I really saw what I said I saw.

Clearly, the geographical distribution of species can never be established, except in the barest outline, from herbarium specimens alone. The main virtue of collecting specimens from across a wide geographical range is to sample the variation of a plant across its range, not to demonstrate the range itself, which is best determined by fieldwork. Herbaria do, however, have an obligation to store voucher material, which helps establish the trustworthiness of identifications made in the course of fieldwork for biogeographical or ecological studies, or any other plant science research. This role is played down by Clifford *et al.* (1990), who note that voucher specimens are rarely studied. But this is more a comment on the perceived value of the research being vouched for than on the need for vouchers. which do not have to be complete specimens (especially with the advent of molecular technology), nor even specimens at all; in some cases images are sufficient.

I have reservations, therefore, about Forman & Bridson's claim that the herbarium should be a comprehensive data-bank. An additional point often put forward is that herbaria contain information of enormous value about the presence and characteristics of plants and vegetation that no longer exist. Sometimes, too, herbarium specimens can be used to answer questions that were wholly unanticipated when the specimens were collected (e.g. to trace eutrophication of lakes : Flower 1986). The problem here is that there is no means of planning rationally for such eventualities : it is difficult to make a convincing argument for expanding herbarium collections now, on the basis that they may be useful in the future for purposes as yet unknown.

What, then, about herbaria as means of identification? Herbaria clearly do have such a role at present, but I would suggest that it will diminish. Why should it be necessary to refer to specimens for identification rather than to published descriptions and keys in floras, monographs or computer databases? I can think of two reasons. Firstly, perhaps it is impossible to construct publishable descriptions or diagnoses for every species, because the characters that are necessary for discrimination cannot be defined or communicated. This I reject as untrue, and so in effect does the International Code of Botanical Nomenclature (Greuter *et al.*, 1988). Secondly, then, if description or diagnosis is possible, perhaps it is easier or less expensive to identify plant material by reference to herbarium specimens. This could only mean that published descriptions and diagnoses are poor or unavailable (because they are contained in rare or out-of-print books, written in a foreign language, etc). Who would dream of collecting and pressing plants, transporting them to one of the few towns of cities world-wide with a good herbarium, and waiting for a taxonomist to have the time to identify them by matching them with herbarium specimens, if it were possible instead to rely with confidence instead upon one's own efforts, aided by a good field guide of Flora? I would dare to suggest that for 90% of the British Flora, herbarium specimens are irrelevant as a means of identification; there is a new Flora (Stace 1991), the older but still much respected work of Clapham *et al.* (e.g. 1981), a multitude of good field guides for the layman (e.g. Fitter & Fitter 1984) and handbooks on particular groups (e.g. Meikle 1984). If all these were found inadequate, most people would probably choose next to consult one of the many competent naturalists scattered across Britain, before finally resorting to herbarium identification. But Britain has a small flora, which has been studied and well documented for many years. Other parts of the world are not so fortunate and here, for identification, matching with herbarium specimens may be the only way to proceed; there are still countries, e.g. Burma, for which no written Flora is yet available or even begun. And there are many plant groups for which existing accounts, in Floras or monographs, are almost useless, except perhaps to herbarium taxonomists. However, we can surely expect that, in time, every area of the world will develop as good or better botanical literature and expertise as Britain has today, although this will certainly take many decades. Thus, as good Floras become available for more and more areas it will become increasingly difficult to argue for continued collection and storage of herbarium specimens on the basis that they are needed to support identification services. In fact, it is the duty of herbarium taxonomists to ensure that, as far as possible, herbaria become largely redundant for identification, by providing user-friendly (but scientifically rigorous) floras, monographs, field guides, databases and identification programs. Clearly, the more support there is for basic taxonomy, the more quickly this can be done.

I have already noted that the use of specimens as types may not be the only possible basis for the correct nomenclature of "preservable" plants, but while it is, herbaria will have to exist to house them. However, there is already enough herbarium capacity world-wide to hold the types of all known or as yet undiscovered land plants. This is obvious from a quick comparison between the estimated total number of land plant species world-wide (between 10^5 and 10^6 : see e. g. Stace 1989) and the number of specimens already in herbaria. In Britain alone, the collections in the four largest British herbaria (Kew, the Natural History Museum, Manchester and Edingburgh) together contain around 15×10^6 specimens. A very limited pruning of existing collections, therefore, would create plenty of space for new types.

Certainties : So, if the use of specimens as types is questionable and there is in any case enough space already to store all the types that might be required, and if herbaria have a limited life as a means of identification and cannot ever be comprehensive data-banks, what then is the rock upon which the future of herbaria can be built and defended? Simply this : that herbarium collections represent an extraordinarily efficient way of storing plant material for study. Classification is based on description and comparison, and comparison is made much easier if the specimens being compared are physically close. This is not because taxonomists can then more easily make "intuitive" judgments based on *Gestalt.* Physical proximity is needed to facilitate the normal iterative processes of scientific method, in which the results of one comparison or analysis suggest hypotheses that are evaluated through further comparisons, often using different characters. One way to do this is to grow plants alongside each other in a botanic garden, and indeed, this is an excellent way to proceed. Living plants have many advantages for taxonomists. They are renewable, providing a potentially everlasting supply of material for study (and not only for taxonomists but also for biochemists, physiologists, molecular biologists and other plant scientists). They can be grown in different conditions to test the extent of phenotypic plasticity. And they are in pristine condition, whereas even the best herbarium specimen is a degraded and often partial remnant. But to be set against these advantages are the costs of maintaining living plants, in horticultural expertise, labour and materials, record keeping, control of the growing environment, administrative overheads and space. The costs can be minimized if the plants are kept dormant until required (as seed or frozen tissue), while unorthodox management of woody species, by coppicing or pollarding, can aid economic use of precious space. Even so, living collections are expensive compared with herbarium collections and it is rarely possible to maintain more than a few different genotypes of each species or lower taxon. Keeping research collections of tropical or subtropical species under glass in temperate countries like Scotland is so expensive that, from an economic standpoint, it would often be better to destroy plants and re-collect them later, rather than to maintain them, if it is likely that they will not be studied for a couple of years; there are many reasons, of course, why one should often overrule the dictates of economy. Besides all this, it is increasingly difficult to arrange export of live material from some countries, which fear exploitation by foreign industry.

The herbarium, then, is an extremely economical way to store huge numbers of specimens, in such a way as to facilitate comparison. It is not a just mausoleum for special specimens, the types, important though these are: it is primarily a store of material for study and use. The specimens are not themselves plants and we should not pretend that they are. They are remnants, which have lost much through decay, dehydration, abrasion and evaporation of volatiles, but which retain much of the form of the original plant, largely because of the resilience of the plant cell wall; many specimens have also been subjected to chemical treatments that remove waxes, oils and much else, either during collection (e.g. using the wet "Schweinfurth" method : see Forman & Bridson 1989) or subsequently, as a result of measures taken to discourage pests. Plants that are too large to fit on standard herbarium sheets are usually trimmed and bent until they do fit. Colours change and the habit and architecture of the plant are often obscured. Few specimens have the beauty of the living plant. All this means that the picture of a plant that we get from herbarium specimens is very incomplete, which in turn means that comparisons based on them are also incomplete. But although much is missing from a herbarium specimen, a great deal remains of the morphology and anatomy of the original plant, much more indeed than is usually studied, even by the monographer. Some phytochemical analyses can still be made, and DNA can also survive. Thus, using this material, a remarkably good beginning can be made, cheaply, which provides a basis for planning more detailed and extensive studies on living plants, in the botanic garden or in nature. In this way the best use is made of the limited resources - human and material - that are available to support taxonomy.

When herbaria are seen in this light, there can be no excuse for those who would claim that the time for collecting specimens is past, or that everything except type specimens can be destroyed without loss. Types and other material of historical importance need to be treated with especial care, but other specimens are also essential. They are the basis for morphological studies and can also be used to supply pollen, seed, anatomical sections, surfaces, etc. for detailed study. Specimens or parts of specimens are inevitably used up as a result of the research done upon them and new ones must be collected (provided, of course, that similar populations of the plant are still accessible in nature). Furthermore, there is a need for new kinds of collection, to satisfy new needs. For instance, herbaria must adapt to meet the challenge of providing for molecular approaches. Ecologists and foresters require keys, illustrations and descriptions that allow identification of non-reproductive and juvenile plants, and so herbaria will need to increase collections of seedlings, sterile lower branches, and even bark and other bulky samples. And, if we wish to make further progress in understanding microevolution in plants, extensive population sampling will be necessary, both for conventional morphological analysis and for molecular and cytological studies.

To those who have to pay for herbaria, from private or public funds, these demands for marked increases in the size and scope of collections may be alarming. We must say to them that this is the price (and a very modest price it is) of a proper understanding of biodiversity and an adequate underpinning of other plant science research; the *quid pro quo* for the financier must be increased focusing of the research programmes associated with each herbarium and an assurance that overlap is minimal between the programmes of different herbaria. Davis & Heywood said much the same nearly 30 years ago : "can governments be expected to go on expanding their herbaria indefinitely? Sooner or later some international co-operation (let alone national co-operation) on policy will have to be faced" (Davis & Heywood 1963). This is not easily achieved in a world that at present values the free market and individual enterprise above central planning.

EPILOGUE

If any of the current concern shown for biodiversity by politicians and the public they represent is real rather than rhetoric, then taxonomists have an essential and expanding role to play in the future; no-one else can measure, describe and document diversity. In turn, plant taxonomists need herbaria. As I have said, this is not primarily because nomenclatural rules (which in my experience are not understood and appreciated by other botanists, let alone accountants) at present dictate that the use of names is to be determined by reference to actual specimens, but because herbaria represent the best available low-cost means of storing raw material for scientific research. Modifications will be required to traditional practices, to support new techniques and approaches, but herbaria have a vital and dynamic future and plans should be made for expansion, not contraction or stasis.

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